Pegasus Technologies' Mercury Specie and Multi-Pollutant Control Project

Benefits Presentation

Clean Coal Power Initiative

- Round 2 -

Installation and Testing of Critical Sensing Devices to Monitor and Control Power Plant Inputs and Emissions

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Outline

- **Executive Summary**
- **Project Information**
  - Plant, fuel, cost, location , and schedule
  - Team members
  - Artificial Intelligence (AI) in power plants
  - Neural networks in power plants
  - Input control: efficient use of raw materials
  - Output Control: reduced mercury emissions
  - Neural network elements
- **Estimated Benefits**
  - Approach
  - Market penetration assumptions
  - Sootblowing
    - Annual emissions reductions from neural network sootblower optimization
    - AI sootblowing system

Outline (continued)

- **Estimated Benefits (continued)**
  - Advanced combustion optimization, coal flow and fuel staging
  - Advanced Electro-Static Precipitator (ESP) optimization
  - Advanced Flue Gas Desulfurization (FGD) optimization
  - Unit optimization
  - Regional
  - National
- **Conclusions**
- **Supporting Material for Estimating Benefits**
  - Assumptions
  - Advanced FGD optimization assumptions for determination
  - Advanced combustion optimization, coal flow and fuel staging assumptions
  - Optimization across the unit

Executive Summary

- **Pegasus Technologies, Inc., a developer of power plant control and optimization technologies, will demonstrate the capability of AI for increasing control of mercury and other pollutants from an existing power plant**
- **Pegasus Technologies will retrofit an existing 890 MW coal-fired utility boiler in Houston, Texas, burning a mixture of 70% Texas lignite and 30% Powder River Basin sub-bituminous coal**

Executive Summary (continued)

- **Using AI and simulation sensors, including neural network-based technologies, Pegasus Technologies will demonstrate:**
  - Capability to maximize the proportion of Mercury (Hg) species that are easy to remove from the boiler
  - How integrating state-of-the-art sensors, controls, and advanced analysis techniques into multiple facets of existing plant operation can lead to improved economics and environmental compliance

Project Information

Plant, Fuel, Location, Cost, and Schedule

- **Installation of AI and simulation sensors on an existing plant, including neural network-based technologies, to monitor and control efficient use of power plant raw materials and to reduce air emissions**
- **A mixture of 70% Texas lignite and 30% Powder River Basin sub-bituminous coal at existing 890 MW coal-fired unit**
- **Location: Texas Genco Limestone Plant, Houston Texas**
- **Project Cost: $14.2 million (DOE Share: $6.1 million)**
- **Schedule:**
  - 2005 Project Start
  - 2007 to 2008: Construction
  - 2008 to 2011: Operation

Project Information (continued)
Team Members

- **Pegasus Technologies, Incorporated (Chardon, OH)**
  - Developer of power plant control and optimization technologies
- **Texas Genco (Houston, TX)**
  - Owner of Limestone Power Plant in Leon County, Texas

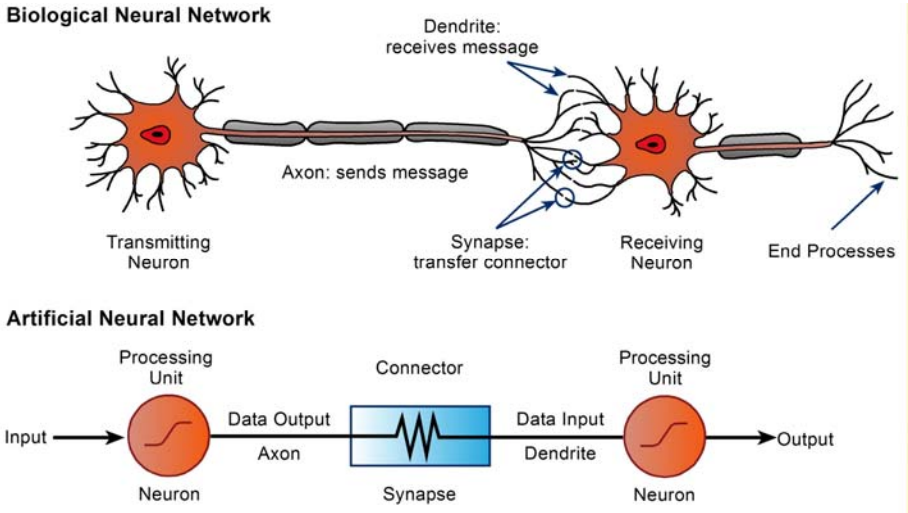
Project Information (continued)
Artificial Intelligence in Power Plants

- **AI is the science and engineering of making intelligent machines, especially intelligent computer programs**
- **AI in power plants**
  - Minimize emissions by balancing plant process conditions
  - Maximize efficiency by maintaining precise control
  - Maximize total power output by minimizing auxiliary power use
  - Minimize operating costs by limiting process excursions
  - Minimize reagent use by managing pollutant formation
- **Artificial intelligence includes:**
  - expert systems,
  - symbolic manipulation, search and planning strategies,
  - genetic algorithms,
  - most recently, neural networks

Project Information (continued)

Neural Networks in Power Plants

- **“Learn” and derive meaning from complex, imprecise, or noisy data, extracting patterns that would otherwise be imperceptible**
- **Can be an "expert" in a category of information, and be given "what if" questions to analyze the information**
- **Greatest power is their ability to generalize from previous information and develop possible similar patterns for future use**

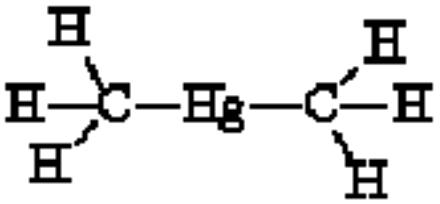


Project Information (continued)
Input Control: Efficient Use of Raw Materials

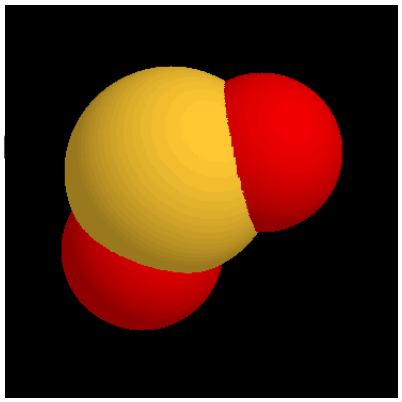
- Continual adjustment of boiler operations to improve heat rate efficiency
- Improved fuel/air ratio control
- Improved adaptability to different grades of coal
- Reduced variability in superheat and reheat temperatures
- Reduced forced outages
- Increased cost-effectiveness and profitability, and maximized ramp rate

Project Information (continued)
Output Control: Reduced Mercury Emissions

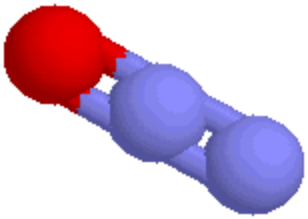
- **Hg Control**
  - Metallic Hg is difficult to remove from flue gas
  - Adjusting parameters during combustion optimizes the speciation process and maximizes Hg capture
  - Hg absorbed on fly-ash particles is removed by conventional particulate control equipment
- **Additional emission control enhancement**
  - Particulate nominal removal efficiency: 99.8% nominal
  - SO_2 nominal removal efficiency: 90%
  - NO_x reductions: 10 - 40%



Dimethylmercury



SO_2



Nitrous Oxide

Project Information (continued)

Neural Network Elements

- Intelligent sootblowing
- Combustion optimization, coal flow and fuel staging systems
- ESP optimization
- FGD optimization
- Hg specie

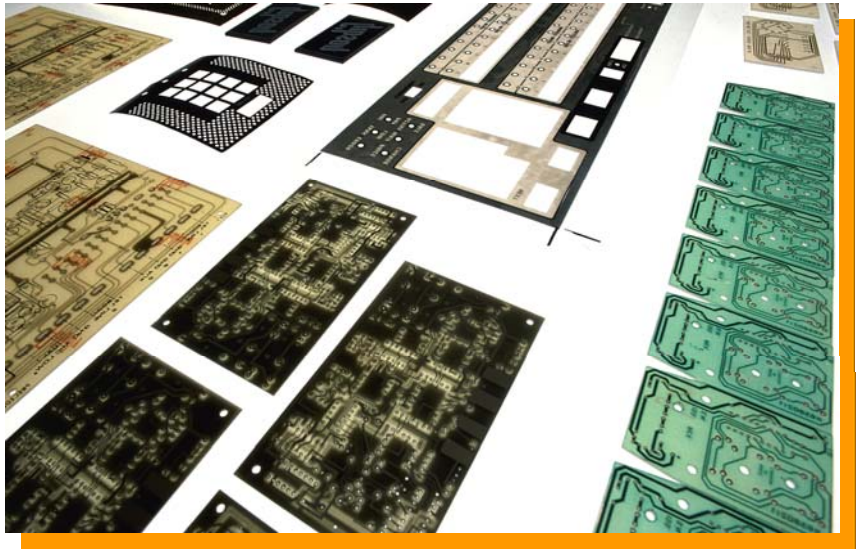
  control system
- Unit optimization

Estimated Benefits
Approach

- **Determine market penetration for the neural network sootblowing system**
  - Compare emission reductions of the system to the total emissions of U.S. installed capacity
- **Calculations were based on:**
  - A 500 MW plant for combustion optimization coal flows and fuel staging systems
  - A generic plant for ESP optimization
  - A 600 MW plant for FGD optimization
  - A nominal plant for unit optimization

Estimated Benefits (continued)
Market Penetration Assumptions

- **Market penetration for the Neural Network Sootblowing System is assumed to be 47 GWe**



Estimated Benefits (continued)

Annual Emissions Reduction from Neural Network Sootblower Optimization

Pollutant	Neural Network Sootblower Emission Reductions, tons/year	All Boiler Emissions, tons/year[1]
NO_X	196,320[2]	3,656,988
CO_2	6,114,000[3]	2.14 billion
SO_2	30,120[3]	10,149,019
Particulate	1,490[3]	491,978

[1] Basis: All coal-fired power plants in the U.S. using the NETL Plant Database

[2] Basis: Technology market penetration of 47 GWe & 30% NO_X reduction

[3] Basis: Technology market penetration of 47 GWe & 2% emissions reduction

Estimated Benefits (continued)
Artificial Intelligence Sootblowing System

Process	Benefits	Annual Savings
NO_X Reduction	5% to 10%	$50,000
SO_2 Reduction	Slight reduction	$1,000
Load Stabilization	Reduce steam temperature and pressure fluctuations by up to 50%	$300,000 to $600,000
Heat Rate Improvement & Reduced Fuel Consumption	0.5% to 2% with concurrent multi-pollutant reduction	$200,000 to >$500,000

Estimated Benefits (continued)
Advanced Combustion Optimization, Coal Flow and Fuel Staging

Process	Benefits	Annual Savings
Hg Control and Reduction	Environmental compliance	Dependent on market credit price
NO_X Reduction	10% to 40% lbs/MMBtu	$1,280,000
SO_2 Reduction	Moderate reduction	$250,000
Heat Rate Improvement	0.5% to 2% with concurrent multi-pollutant reduction	$200,000
Total Operating Savings		$1,730,000

Estimated Benefits (continued)
Advanced ESP Optimization

Process	Benefits	Annual Savings
Hg Capture	Improved particulate bound elemental Hg capture	Dependent on market credit price
Electrostatic Precipitator	Increase control of Hg capture	Reduced over-design of ESP
Particulates, Opacity	Maintain Hg capture while maintaining commercial value of byproducts	Fly-Ash sales dependent upon unit size
Auxiliary Power	Improved control resulting in reduced parasitic power load	More MW's to the grid $300,000 to $500,000

Estimated Benefit (continued)
Advanced FGD Optimization

Process	Benefits	Annual Savings
SO_2 Removal	Efficiency gain - improved damper and pH control- Avoided SO_2 credits cost	$317,000 to $797,000
Operational Cost	Reduced chemical and parasitic power consumption	$67,000 to $154,000
Scrubber Process Control	Limestone blinding can be prevented	(for 2 incidents) $182,000
Unit Maintenance	Early detection of faulty pH probe and limestone particle sizing problems	(Emergency probe replacement) $65,000

Estimated Benefits (continued)
Unit optimization

Process	Benefits	Annual Savings
Hg & Multi-Pollutant Control	40% to 50% reduction	Dependent on market credit price
NO_X Reduction	10% to 40% lbs/MMBtu	$1,280,000
SO_2 Reduction	Moderate reduction	$250,000
Heat Rate Improvement & Reduced Fuel Consumption	0.5% to 2% with concurrent multi-pollutant reduction	$200,000 to $500,000
Total Operating Savings		$2+ Million

Estimated Benefits (continued)
Regional

- **Reduced air emissions, including Hg**
- **Infrastructure requirements for fuel and chemical delivery are minimized**
- **Power plant availability is improved, reducing consumer costs**
- **Additional energy available for region due to decreased auxiliary power requirement**

Estimated Benefits (continued)
National

- **Widespread application of the technology is expected to have:**
  1. the capability to increase plant efficiency and reduce harmful emissions of Hg
  2. increased control of SO_2, NO_X, and particulate emissions
  3. reduced water usage
- **Technology can be directly retrofitted into existing coal-fired power plants or integrated into future new plant designs**

Estimated Benefits (continued)
National

- **Optimizing coal usage will conserve our domestic coal reserves and reduce dependence on oil and gas imports**
- **Further America's environmental initiatives:**
  - FutureGen
  - Hydrogen

Conclusions

- Demonstration of plant-wide advanced control and optimization systems will minimize emissions of Hg and other pollutants into the atmosphere
- Improved knowledge of plant conditions will also provide the capability to maximize plant efficiency for electricity production
- The project also addresses concerns that higher Hg concentrations in existing by-products may adversely affect the commercial value of those by-products
- This technology is expected to have widespread application since it can be directly retrofitted to existing coal power plants or integrated into future new plant designs

Visit the NETL web site for information on all Power Plant Improvement Initiatives and Clean Coal Power Initiative projects

www.netl.doe.gov/technologies/coalpower/cctc

Supporting Material for Estimating Benefits
Assumptions

- **Estimated benefits assumptions – advanced FGD optimization assumptions for determination**
- **Estimated benefits assumptions – advanced combustion optimization, coal flow & fuel staging systems**
- **Benefits estimate optimization across the unit**

Supporting Material for Estimating Benefits (continued)

Advanced FGD Optimization Assumptions for Determination

- 600 MW operating at 80% capacity
- Coal with 2% sulfur content (17 tons per hour at full load)
- Absorber designed for 90% removal efficiency
- Original average flue gas bypass amount is 20%
- Effective SO_2 removal rate (originally 72%)
- Limestone usage of 40 tons per hour at full load
- Spray tower has 5 levels
- Recycle pumps consume 4.5 MW at full load operation
- Internal power costs $45 per MW
- SO_2 credits sell at $165 per ton
- Limestone costs $18 per ton

Supporting Material for Estimating Benefits (continued)

Assumptions - Advanced Combustion Optimization, Coal Flow & Fuel Staging Systems

- Hg speciation for increased post-combustion removal (estimated mercury capture by 40% to 50%)
- NO_X reduction of 10% - 40%
- Heat rate improvements 0.5% –2.0% or higher
- Concurrent SO_2 and CO_2 reductions
- Reduced fuel consumption
- Reduced failure/outages
- Increased operating controllability and flexibility
- Reduced operational costs for existing pollution technologies
- Continuous optimization of multiple variables through automation
- Reduced capital investment compared to alternative emissions reduction solutions

Supporting Material for Estimating Benefits (continued)

Optimization Across the Unit for:

- Hg speciation for increased post-combustion removal (estimated to improve Hg capture by 40% to 50%
- NO_x reduction of 10% to 40%
- Heat rate improvements 0.5% – 2.0% or higher
- Reduced fuel consumption
- Concurrent SO_2 and CO_2 reductions
- Reduced fuel consumption
- Increased operating controllability and flexibility
- Reduced capital investment compared to alternative emissions reduction solutions